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Differences and similarities in the Cocos–North America and Cocos–Caribbean convergence, as revealed by seismic moment tensors

Marco Guzmán-Speziale*, F. Ramón Zúñiga

Centro de Geociencias, Universidad Nacional Autónoma de México, Blvd. Juriquilla 3001, Querétaro 76230, Mexico

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A B S T R A C T

We investigate the differences and similarities in Cocos–North America and Cocos–Caribbean convergence, reflected by seismicity and seismic moment. We use well-located hypocenters of earthquakes in the convergence margin, as well as within the subducted slab. We sort these data by number of events in the two converging margins, and by their magnitudes. We also use this database to determine an improved geometric model of the subducted slab. We find a shallow-dipping subducting Cocos plate underneath North America and a steeper dip slab under the Caribbean plate. The transition between them appears to be smooth.

Centroid Moment tensor solutions indicate that almost all of the thrust-faulting earthquakes along Cocos–North America take place at shallow depths. Normal-faulting events along this margin only take place to depths of 100 km. Thrust- and normal-faulting events take place at all depths along the Cocos–Caribbean margin. Cummulative scalar seismic moment for shallow, thrust-faulting events, is larger along Cocos–North America.

T axes of intermediate-depth, normal- and thrust-faulting events show that the subducted Cocos plate is in maximum tension along the direction of maximum dip. Azimuth of earthquake slip vectors for shallow events along the Cocos–North America margin agree well with the direction of plate convergence. They do not agree along the Cocos–Caribbean margin; instead, agreement is found with Cocos–North America relative plate motion.

Compensated Linear Vector Dipole (CLVD) ratio, which measures how different a seismic source is from a pure double-couple, along both margins is inversely proportional to scalar seismic moment, indicating that for larger magnitudes rupture is closer to a double-couple mechanism than at smaller moments.

1. Introduction

The Middle America trench (MAT) serves as a plate boundary between the subducting Cocos (Coco) and overriding North America (Noam) and Caribbean (Carb) plates, (Fig. 1). The plate boundary between Noam and Carb is defined by the Swan and Motagua-Polochic (Motagua for short) fault zones (Fig. 1), although it is not clear where or how (or if at all), the Motagua-Polochic reaches the MAT. Consequently, the transition in overriding plate for the subduction of the Cocos plate is not clearly defined, but many authors agree that it is located somewhere around longitude −96° (Fig. 1) (e.g., Malfait and Dinkelman, 1972; Muehlberger and Ritchie, 1975; Plafker, 1976; Burkart, 1978, 1983). Guzmán-Speziale et al. (1989) and Guzmán-Speziale and Meneses-Rocha (2000) define the triple junction of the three plates as a wide zone of deformation which spans most of the state of Chiapas, in Mexico (Fig. 1); this would extend the overriding Caribbean plate to the west, to about longitude −96°.

There have been several GPS studies in the area in recent years (e.g., DeMets et al., 2000; DeMets, 2001; Lyon-Caen et al., 2006; DeMets et al., 2007; LaFemina et al., 2009; Rodriguez et al., 2009; Franco et al., 2012). Only two of them directly address the plate boundary problem. Lyon-Caen et al. (2006) propose that the triple junction covers a wedge-shaped area 400 km wide south of the Motagua-Polochic system and includes a coastal microplate between the Middle America trench and the Central American

* Corresponding author.
E-mail addresses: marco@geociencias.unam.mx (M. Guzmán-Speziale), ramon@geociencias.unam.mx (F.R. Zúñiga).

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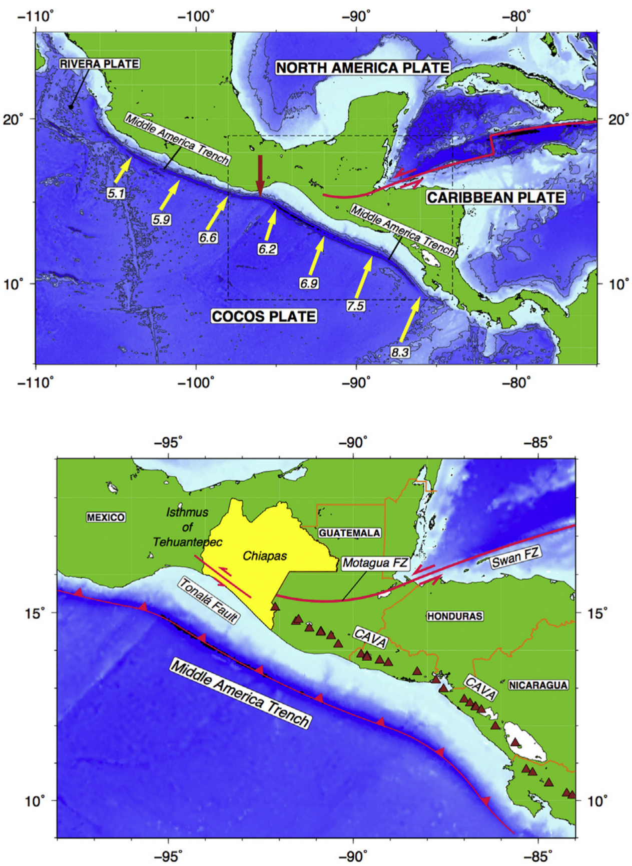

Fig. 1. Tectonic framework of the Cocos plate convergent margin. Top- General view. Yellow arrows indicate direction and speed (in cm/yr) of plate convergence, calculated from the Euler poles given by DeMets et al. (2010) for Coco–Noam (first three arrows, from left to right), and Coco–Carb (last four arrows). Length of arrow is proportional to speed. Red arrow shows location of the −96° longitude. Box indicates location of lower panel. Bottom- Location of features and places mentioned in text. Triangles indicate volcanoes of the Central American Volcanic Arc (*CAVA*) with known Holocene eruption (Siebert and Simkin, 2002). Figures drawn with *The Generic Mapping Tools* (Wesseel and Smith, 1991; Wessel et al., 2013). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

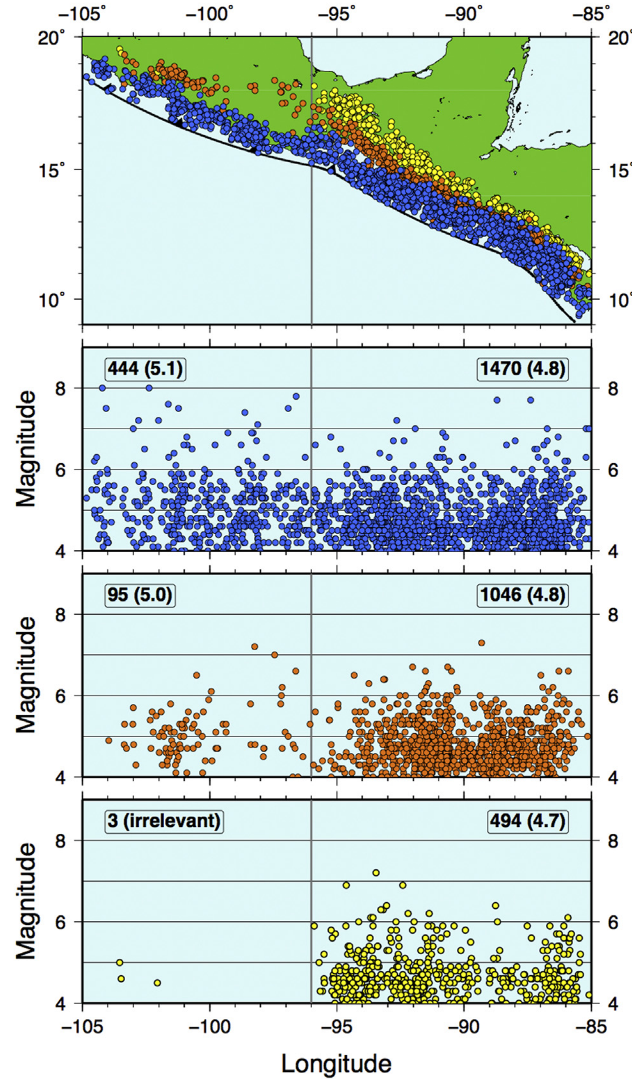

Fig. 2. Seismicity along the convergent margin. Top: Map view. Blue circles are shallow ($z \leq 60$ km) hypocenters; orange, intermediate-depth ($60 < z \leq 100$ km); yellow, deep ($z > 100$ km). Next three panels: Earthquakes as a function of longitude and magnitude for shallow (blue dots), intermediate (orange), and deep (yellow) hypocenters. Numbers indicate number of events on each convergent margin, with average magnitude in parenthesis. Gray line in this and subsequent figures mark the −96° longitude. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

volcanic arc. Franco et al. (2012) suggest that the Motagua fault may be extrapolated to the west, reaching the MAT, as the “Motagua fault west”, although they do not provide evidence that this is the case.

Several authors (e.g., Bevis and Isacks, 1984; Burbach et al., 1984; Pardo and Suárez, 1995; García-Quintero, 2007) found a change in the dip of the subducting slab at longitude −96°. The shape of the trench changes abruptly here, as well: To the northwest, its maximum depth is about 4500 m and it is narrow with almost no continental platform. In contrast, from this point to the southeast the trench widens, reaches depths of about 5500 m and possesses a well-defined continental platform, 100 km in width (Fig. 1). For the purpose of this work, then, the Cocos plate is being subducted underneath the North America plate along the Middle America trench, from the Cocos–Rivera–North America triple junction (at about longitude −105°) to the Cocos–Caribbean–North America triple junction (longitude −96°). From there to about longitude −85° (where the trench looses its trace) the Cocos plate is being subducted underneath the Caribbean plate (Fig. 1).

Uyeda and Kanamori (1979) and Uyeda (1982) have argued that along plate margins of the *Chilean type*, those where the overriding plate advances towards the subducting plate, the *Wadati-Benioff zone* (that is, the subducted slab, as defined by hypocenters) is shallow-dipping, great ($M \geq 8$), shallow, thrust-faulting earthquakes occur along the plate interface, the trench is shallow, and there is a well-developed accretionary prism. In the *Mariana type*, the overriding plate is stationary with respect to the subducting plate or retreats from it, the dip of the Wadti-Benioff zone is steep, no great earthquakes take place along the interface, the trench is deep, and there is no accretionary prism. For Uyeda (1982), both modes are present along the Middle America trench: *Chilean type* along the Cocos–North America plate boundary, and *Mariana type* along the Cocos–Caribbean interface. For Jarrard (1986), however, the *Chilean* and *Mariana* types are only end member cases, with most other convergent margins on Earth occupying a continuum between these two. Based on the strain regimes of the upper-plate, Jarrard (1986) defines seven different strain classes, with number one being *active back-arc spreading* and seven *very strongly compressional.* He places Southeast Mexico in number six, *moderately compressional*, and Central America in number three, *mildly tensional.*